Geology, Petrography and Structural analysis of Jada area, Northeastern Nigeria

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Abstract

The study area, forms part of the Hawal massive regarded as an extension of Bamenda massive that forms part of the Cameroun volcanic line in the Northeastern part of Nigeria (Ekwueme 1993). Eighteen samples collected in the study area were used for petrographic analyses in addition to the geological field mapping and structural analysis. The hand specimen descriptions and results of microscopic studies of the collected samples in the area revealed that quartz, feldspar and biotite are the predominant minerals in the rocks exposed, which are mainly granites, gneisses, diorites. Field relations and petrographic analysis suggest the occurrence of alkaline rocks in the study area and series of thermo-tectonic activities that resulted into numerous structural features and emplacement of different rock units that might have significant resource potentials.

Keywords: Adamawa Massif, Pan African Orogeny, Geochemistry, Jada, Northeastern Nigeria

1. Introduction

The study area lies within the southern part of the Hawal Massif which is regionally considered to be part of the basement complex of Nigeria, which consists mainly of Older granites of Precambrian age emplaced during Pan African orogeny about (450-750 Ma) and the associated metamorphic rocks. The study area covers Jada area and its environs (Fig.1). It lies between longitude 12° 7´N - 12° 12´N and latitude 8°42´E-8° 48´E within the first edition of the Nigerian 1:50,000 scale, NW and SW sheets 217 (Fig. 2). It covers about 102.3 km^2 and shares an international border with Cameroun Republic to the eastern axis.

The research work conducted in the area under this study involved extensive geological mapping of the exposures, description and measurement of the attitude of features such as faulting, folding, veins, foliations, joints as expressed in the rock types of the study area, followed by assessment of petrography. The petrographic studies revealed the mineralogical composition, which together with results from structural analysis obtained were used to give a better understanding of the geology and resource potentials of the of the study area.

Although the study area falls in the Hawal massif, an important segment of the Northern Nigerian basement complex of Pan African orogeny, endowed with abundant mineral resources, but there are no works on the petrography and structural geology of the rocks in the area to shade more lights on the petrology and possible links of the structures to known mineralizations and hydrogeological resources in the area.

2. Regional Geology of the Study area

Most of the previous works carried out were regional in extent relating to the Northern region and the basement complex in general, but the work of Obiefuna et al (2012) at Wuro Bayare, a neighbouring community to the study area shows that biotite, quartz, muscovite, feldspar, plagioclase are the dominant minerals of the granitic rocks exposed there from petrographic analysis. Bassey (2006) reported the character of the magnetic residual field over Hawal massif which supports the satellite imagery results obtained and the structural geology of the area. The work of Baba (1997) on the geochemistry of alkali feldspar from Liga hills agreed with the fractionation process in the magmatic origin of the granites of Northern basement complex because of their inter elemental relationship between them, meaning that they were formed from melts generated by anatexis of older crustal materials.

The work of Islam et al (1989) divided the eastern Nigeria basement complex into four namely; the Mandara Mountain, Alantika Mountain, Shebshi Mountain and Adamawa Massif. Benkhelil (1986), reported that N-S trending faults system predominate in Lower Gongola Basin and Hawal basement, as in other basement areas of Nigeria which had undergone polyphase tectono-thermal events in the form of magmatism, metamorphism and structural deformations.

Rahaman (1988) observed migmatite gneisses, granite gneiss, early pegmatitic dykes and fine-grained granites, medium grained granites, slightly deformed pegmatite and aplite, dykes and veins are the constituent rock types of the older granites of Nigerian basement complex.

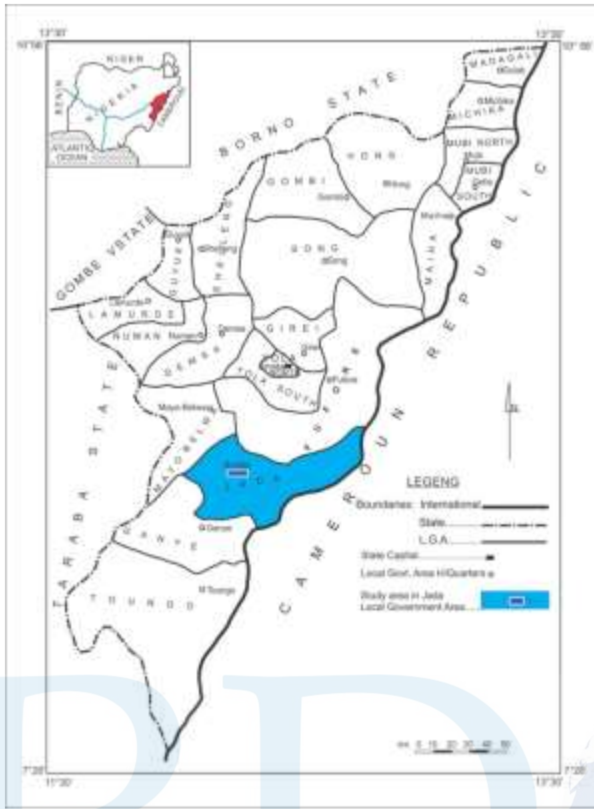

Fig. 1: Map of Adamawa State showing location of the Study area (Source: Adebayo and Tukur, 1999).

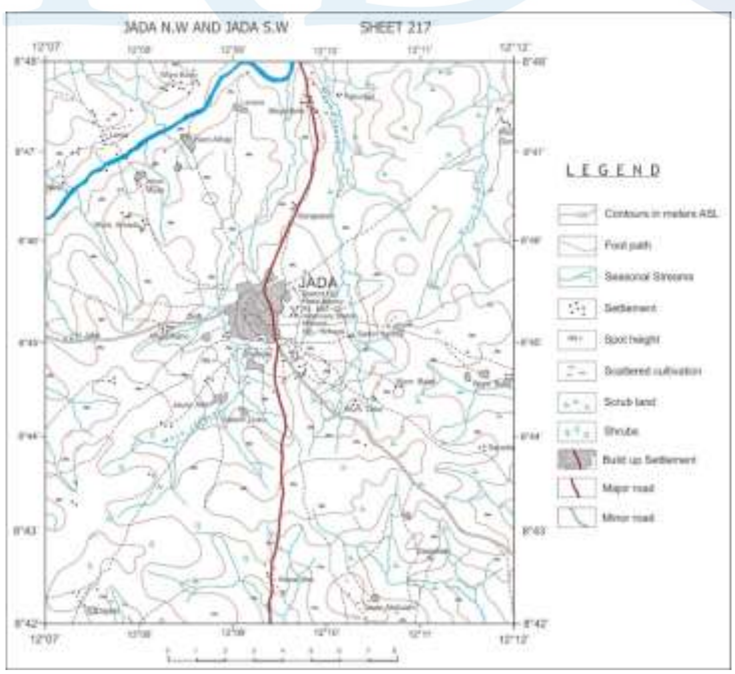

Fig. 2. Topographic Map of the Study Area and Environs (Federal Surveys, 1966)

Ekwueme (1993), classified basement rocks of Northeastern Nigeria to be consisting of migmatites, gneisses, diorites, porphyritic granites, volcanic rocks and alluvial deposits.

The regional works include the regional mapping of northern Nigerian basement complex which is bounded by the sediments of Chad basin and Benue Trough, (Falconer 1911). Fitches et al (1985) carried out a regional geochemical investigation on older granites of Nigeria and concluded that the major and trace elements show calc-alkaline to alkaline affinity.

Olade 1976 ascribed the inadequate geochemical investigations in the basement complex to the paucity of major mineral deposits possibly due to ineffective past mineral exploration or unfavourable geochemical heritage. Carter et al (1963) has petrographically described sericitic rocks in Northeastern Nigeria as non-foliated, green-grey, fine-grained, dense and structureless rocks composed of massive aggregates of sericite and fine mica.

The regional geology of Adamawa state is represented by rocks of different formations (Fig. 3). Essentially the basement rocks such as older granites, migmatite-gneisses of Precambrian age are the oldest, overlain in some localities by sedimentary rocks of Upper Cretaceous to Quaternary (Carter et al., 1963). The crystalline rocks consist of highly metamorphosed rocks mainly the migmatites, gneisses and older granites and these rocks outcrop extensively in the study area occupying greater percentage of the rocks in the state at large.

Extensive Massifs intrude the region from Mandara Hill as Hawal Massif and from Bamenda Hills as Adamawa Massif. Adamawa region encompasses part of an ancient craton that was tectonically active in the geologic past.

Jada falls in the region of crystalline basement rocks. Granitization by intrusion of granites, granodiorites and syenites in the region transformed the older rocks into oriented biotite-granites, porphyritic granites and alkaline granites. These recycled crystalline rocks are located in the north and south fringes of the state. They outcrop at Mubi, Song, Garkida, Ganye, Toungo and Jada (the study area) as ridges consequent to compression during orogenic events.

2.1 Local Geological Setting of the Study Area

The study area is located within the Precambrian basement Complex in the southern part of Adamawa State (Fig.3). The rocks in the area are older granites, migmatite-gneisses, mylonites and cataclasites. Some parts of the study area overlying the basement rocks are the alluvium (Obiefuna et al, 2010). The description of lithologic units in the study area is given as follows:

2.1.1 Older Granites

The Older granites which were emplaced during Pan African orogeny occupy a greater percentage of the study area. These include basic and intermediate intrusives, migmatite-gneisses, quartzites and syntectonic to late tectonic granites (McCurry, 1976). The Older granites are texturally fine to medium to coarse grained intruded by quartzo-feldspathic veins.

2.1.2 Migmatites

These are banded, granular metamorphic rocks containing light colored bands with evidence of partial melting during regional metamorphism. They are rocks of varying lithology, texture and structure, or rocks of metamorphic host and acid injection which may be feldspathic or granitic. Migmatization in the northeastern basement complex preceded intrusion of syntectonic to late tectonic granites. Granitic injection and metamorphic differentiation seem to have been important processes during migmatisation, (McCurry 1970).

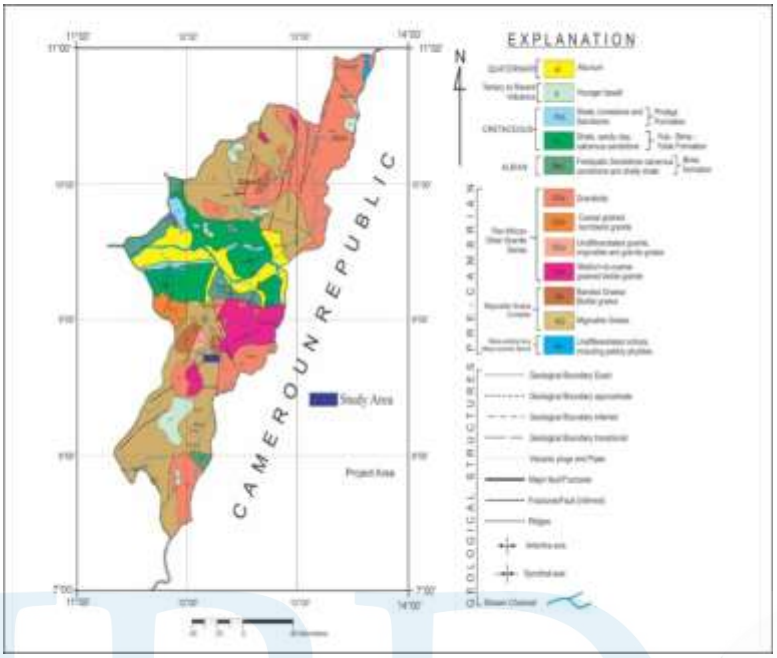

Fig 3. Geologic map of Adamawa state showing the study area (Modified from GSN, 2011)

2.1.3 Gneisses

These are metamorphosed granites characterized by foliated grain of quartz, feldspars and biotite. They exhibit granular texture with foliated and lineated structure.

2.1.4 Amphibolites

These are rocks of metamorphic origin consisting mainly of amphibole of hornblende group and are of regional metamorphism of mafic igneous rocks such as basalt. This rock type was observed at the extreme northern edge of the study area, off the river channel.

3. Field Relations and Analytical Techniques

3.1 Geological Mapping

Extensive geological mapping of the study area was done using designated field equipments and materials. Measurements and description of structures found on the in-situ exposed host rocks were conducted and recorded in the field book and on topographic map. During the geological mapping exercise, boundaries demarcation of rock types in the study area was done by using the GPS to plot the coordinates of the rock boundaries on the map to ensure correct information on the geologic map produced (Fig.4). While carrying out the mapping exercise, lithologic description was carried out which include determination of structural trends such as banding, jointing and orientation of the structures observed, (Fig.5). Rock samples were collected during the fieldwork, for petrographic analysis.

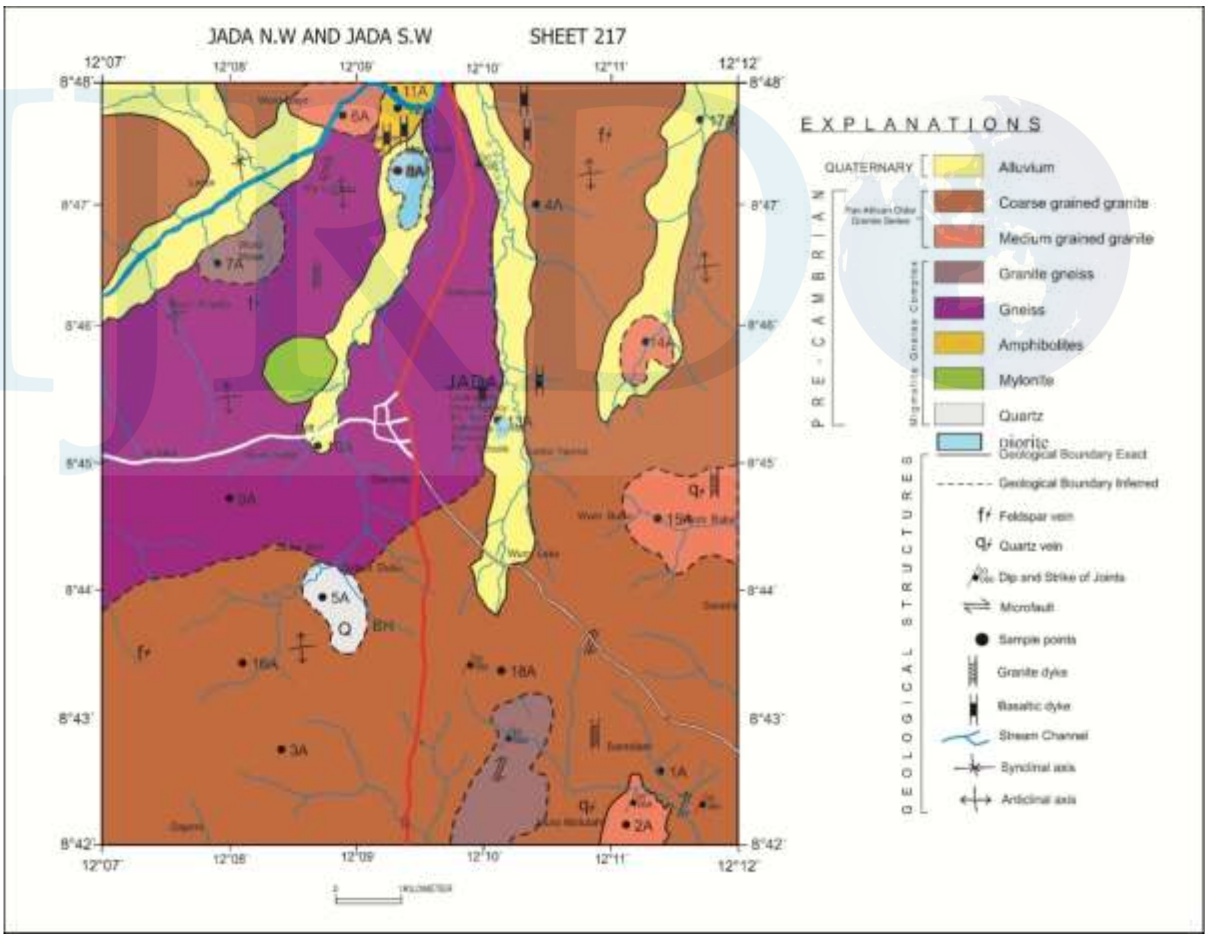

Fig 4. Geological map of the study area

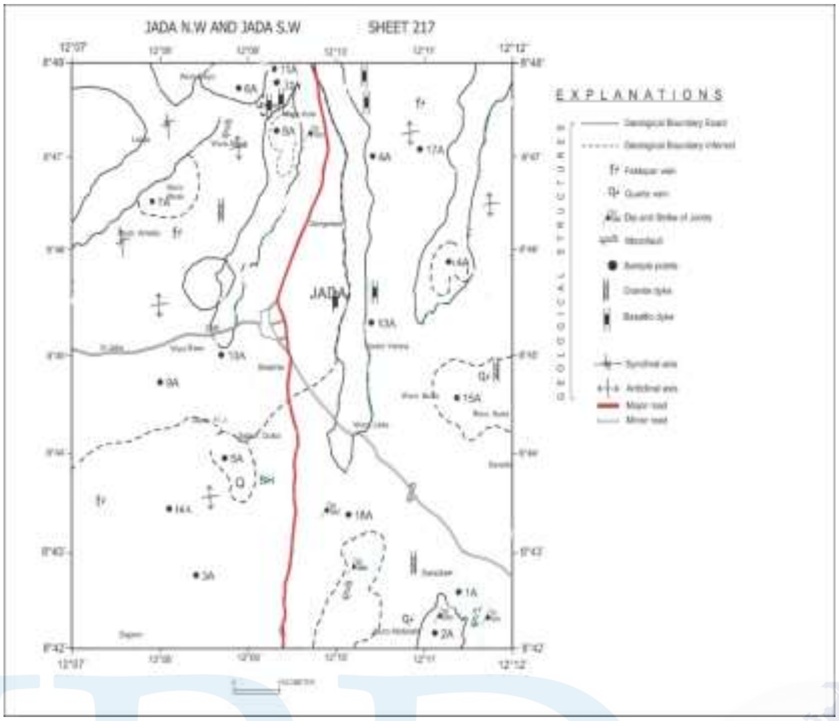

Fig. 5. Structural and sample location map of the study area.

3.2 Petrographic Analyses

Thin sections of 18 samples (Table 1) were prepared in the thin section and research laboratories of Abubakar Tafawa Balewa University Bauchi, Nigeria.

The thin sections were studied under a polarizing microscope (OLYMPUS 107B Model) to identify the rock forming minerals. Observation of the various optical properties was done under, cross polarized light (XPL) and plane polarized light (PPL). Results of this analysis along with the field observation were used to assign rock types of the study area.

Table 1 Description of rock samples and their coordinates.

		Coordinates	
Sample Number	Sample Description	Easting	Northing
1A	Coarse-medium grained biotite granite	12°11' 19.6"	8°42' 33.3"
2A	Coarse grained biotite granite	12°11' 06.2"	8°42' 10.5"
3A	Coarse grained porphyritic granite	12°08' 15.4"	8°42' 50.2"
4A	Medium-fine grained granite-gneiss	12°10' 16.1"	8°47' 01.73"
5A	Quartzite	12°08' 52.7"	8°43' 58.1"
6A	Coarse grained granite gneiss	12°08' 56.9"	8°47' 48.3"
7A	Coarse-medium grained granite-gneiss	12°07' 57.5"	8°46' 30.6"
8A	Medium-fine grained diorite	12°09' 13.0"	8°47' 13.5"
9A	Coarse-medium grained migmatite-gneiss	12°08' 00.4"	8°44' 48 .2"
10A	Coarse grained hornblende granite	12°08' 50.7"	8°45' 00.8"
11A	Amphibolite	12°09' 14.0"	8°47' 58.3"
12A	Massive basalt	12°09' 15.9"	8°47' 51.8"
13A	Coarse-medium grained diorite	12°10' 14.3"	8°45' 15.0"
14A	Coarse-medium grained biotite granite	12°11' 10.7"	8°46' 53.8"
15A	Microgranite	12°11' 15.2"	8°44' 34.0"
16A	Coarse grained hornblende granite	12°08' 05.3"	8°43' 30.1"
17A	Coarse-medium grained migmatite gneiss	12°10' 58.9"	8°47' 03.2"
18A	Coarse grained migmatite gneiss	12°10' 08.7"	8°43' 13.9"

3.3 Structural Features

Several structural features were observed in the field, but the common ones include joints, veins and faults (Table 2, Fig 6). Almost all rock outcrops in the area display significant occurrence of joints with different characters trending mostly NE-SW. Some rocks display few joints some of which are mineralized while others are cross joints as shown in (Fig 6A).

The veins observed in the study area are mostly quartz, feldspathic and quartzo-feldspathic. Open folded feldspathic vein within a coarse grained biotite granite in the study area is given in (Fig 6B). Most of the faults (Fig 6C) observed in the study area are reverse which indicate evidence of extensional movement associated with the Pan- African Orogeny.

Rose diagrams (Figures 7A, B and C) show the trends of joints, veins and faults in the study area taken during the mapping exercise using compass clinometer. A total of 134 strike readings of joints, 70 strike readings of veins and 58 strike readings of faults were obtained from the field and used to construct the rose diagram. The direction of the structural trends in the study area conforms to the general NE-SW structural trends of the Pan African rocks and a pronounced NW-SE trend.

4. Results and Discussion of Petrographic Studies

The hand specimen and thin section description of the representative samples are given below along with their photomicrographs, showing mineralogical distribution.

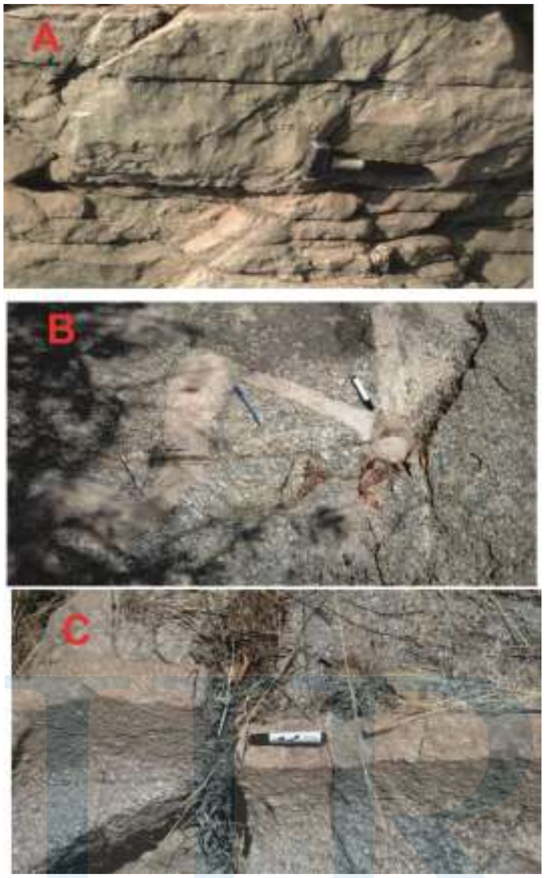

Fig 6. Structural features of the study area

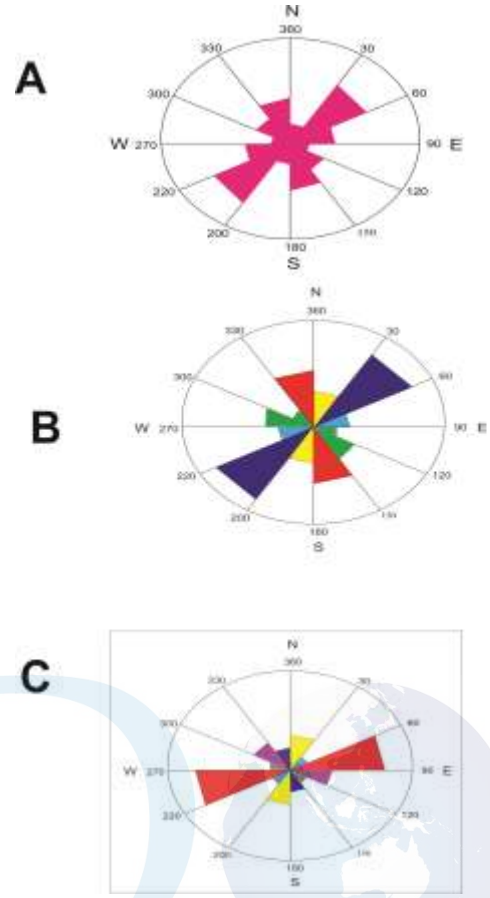

Fig. 7A-C. Rose diagrams respectively showing structural trends of joints, veins and faults

In megascopic view, Sample 1A (Coarse-medium grained biotite granite) is light-grey coloured, hollocrystalline, medium-grained with visible feldspar phenocryst modifying it to have a porphyritic texture. Biotite appears as black shiny flakes observed by using hand lens. In thin section, the rock was examined under magnification of 200 µm and 500µm and shows quartz, orthoclase, feldspar, ilmenite and biotite. The quartz occurs as a well-formed crystal, colourless to grey and partially altered; has low relief, low birefringence, and lack cleavage or twinning. The feldspar present is orthoclase with single twinning. The ilmenite shows

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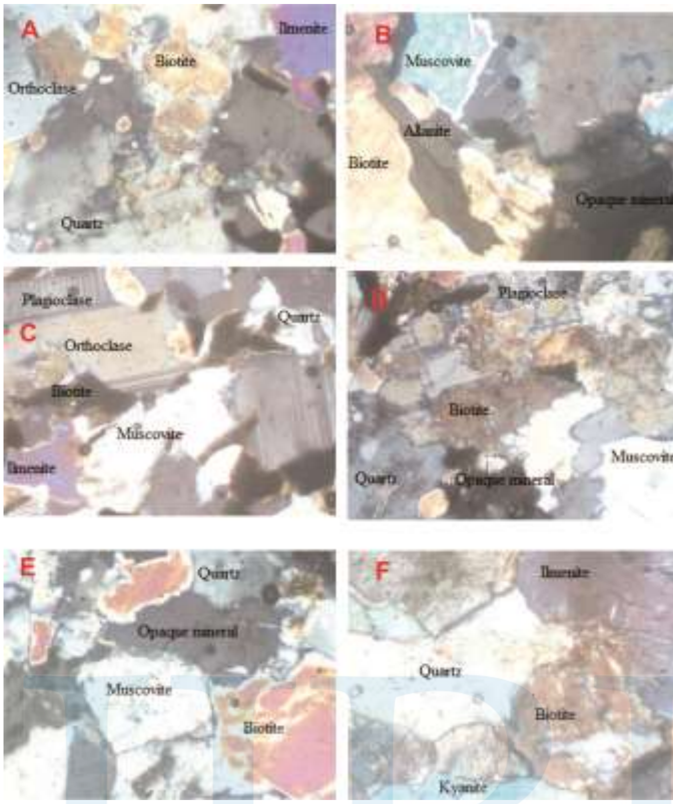

Fig. 8 A-F. Photomicrograph of thin sections

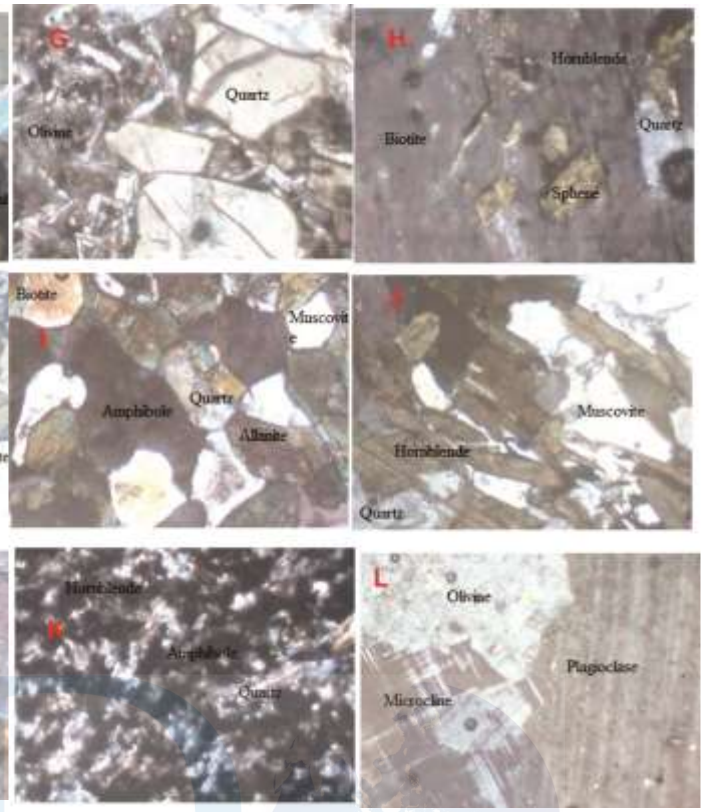

Fig. 8G-L. Photomicrograph of thin sections

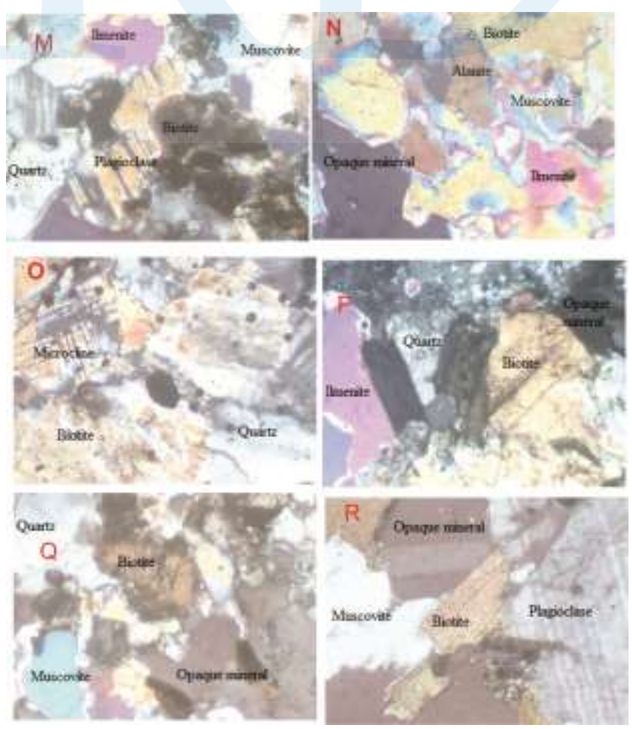

Fig. 8M-R. Photomicrograph of thin sections

purple colouration while biotite in the rock is brownish in colour as shown in (Fig. 8A). Sample 2A (coarse grained biotite granite) in visual observation is melanocratic with a coarse grained equigranular texture. It has abundant dark mineral appearing shiny black, colourless to grey quartz, biotite and muscovite. In microscopic view, the crystals display high relief but alteration occurred in the quartz and biotite crystals. Muscovite appears pale green and seems to have undergone sericitization, evidenced by presence of white flakes sericite. Besides the thin section also have elongated crystals of allanite (epidote) with high relief and brownish colour (Fig. 8B).

Megascopic view of Sample 3A (Coarse grained porphyritic granite) is light coloured, holocrystalline, coarse grained porphyritic textured rock. Allignment of k-feldspar crystals within the ground mass is also seen; biotite flakes appear shiny and dark brown. Quartz is also prominent and appears colourless to faintly coloured. In thin section, feldspar minerals are subhedral, have high relief, low cleavage and simple twinning (Fig. 8C). Quartz shows low alteration, no cleavage, is untwined, have low interference colour and is colourless while biotite appears dark with straight extinction and ilmenite crystals are purple coloured qualifying the rock to be an acidic intrusive igneous rock.

In hand specimen, sample Sample 4A (Medium-fine grained granite gneiss) is hollocrystalline, medium to fine grained textured, fairly pinkish to light coloured and associated with altered biotite and muscovite flakes. The microscopic view of the sample shows mainly plagioclase feldspars having albite twinning, biotite, orthoclase, opaque minerals, muscovite (Fig. 8C). The relief of the minerals is intermediate to high. Biotite shows closely packed cleavage.

Sample 5A (Quartzite) is hollocrystalline in hand specimen and colorless. The sample is marked by several joints along which it easily breaks. Because water enters through these joints and subsequent weathering, the sample appears cloudy. The thin section view shows subhedral biotite, muscovite minerals and quartz mineral with no twinning, low interference colour, colourless, no cleavage with significant alteration (Fig. 8E).

In hand specimen, Sample 6A (Coarse grained granite gneiss) is light coloured, hollocrystalline, foliated containing large crystals of quartz as colourless, black shiny biotite minerals appearing in small proportion and altered muscovite. The thin section shows low to intermediate relief subhedral and anhedral quartz, biotite, ilmenite mineral grains. The quartz and muscovite are altered while ilmenite developed cleavage and biotite underwent sericitization. Accessory minerals like zircon and sphene appear dark brown (Fig. 8F).

In hand specimen, Sample 7A (Coarse-medium grained granite gneiss) hollocrystalline, leucocratic and coarse to medium grained textured with large quartz crystals. Biotite and olivine minerals and little amounts of muscovite predominate the ground mass. The alignment of mineral crystals depicts a metamorphosed rock. In thin section, large subhedral quartz crystals were observed and having inclusions of dark minerals. Other evidence of alteration includes minor fractures on the minerals, elongated olivine minerals, sugary texture together with little appearance of biotite. The minerals showed high relief, low interference colour and lacked twinning. (Fig. 8G). The sample is granite gneiss.

Sample 8A (Medium-fine grained diorite) is massive, melanocratic, medium to fine grained textured under visual observation and contains distinctive dark minerals assumed to be hornblende has few quartz crystals. The rock occurs as small plug shaped outcrop in the study area. In thin section, dark colored minerals dominate the slide and minerals like, hornblende, quartz, olivine and sphene are observed with high relief. Sphene is the dominant accessory mineral with rhombic shape and the opaque minerals are mostly iron oxide, which are however not much (Fig. 8J). The rock is suggested to be a diorite.

The megascopic examination shows that Sample 10A (Coarse grained hornblende granite) is a coarse grained hollocrystalline rock having biotite, muscovite and dominant hornblende and iron oxides, and little quartz. The thin section view shows clearly euhedral and subhedral laths of hornblende, opaque minerals, quartz and muscovite indicating alteration effects. The minerals show high relief, low extinction, low interference colour and low birefringence (Fig. 8M).

The amphibolites (sample 11A), in the study area is fine grained, massive, crystalline and melanocratic rock but contains quartz crystals along fractures. The rocks occur as large boulders at the extreme northern edge of the study area. In thin section, the minerals identified include amphibole (actinolite), hornblende and quartz which show high relief and sugary texture (Fig. 8N).

In hand specimen, the basalts (sample 12A) in the area appears massive (non-foliated), and fine grained. It is a melanocratic rock containing dark coloured minerals, mainly olivine, small inclusion of feldspars. The rock is invaded by a feldspathic dyke, which also intruded the amphibolite and gneisses in the study area. In thin section, it contains microcline and plagioclase feldspars having polysynthetic and simple twinning, and light green coloured olivine minerals (Fig. 8O).

The hand specimen, Sample 18A (Coarse grained migmatite gneiss) is foliated, leucocratic coarse grained, hollocrystalline with visible minerals like quartz, muscovite and biotite. The rock occurs as small exposure surrounded by granitic rocks assumed to be the parent rock which underwent deformation through metamorphism as expressed by minerals foliation and folding of veins clearly seen on the outcrop. In thin section view, large anhedral crystal laths of cleaved biotite and plagioclase with simple twinning dominate the slide. Other minerals include large crystals of quartz, muscovite and opaque minerals appearing with high relief (Fig. 8R).

Based on field relations, a strong indication of multistage tectono-thermal activities took place within the study area. This is evidenced by the numerous structural features and emplacement of variable igneous intrusions and metamorphism. Rocks in the study area generally show alkaline affinity, with abundant mafic minerals and potassium rich feldspars. Mineralogical composition from the amphibolites (e.g. actinolite, quartz and biotite) is speculative that they belong to ortho-amphibolites that form as a result of continuing burial and thermal heating. Petrographic analysis suggests that the massive basalt in the area to be alkaline in nature and is characterized by abundant microcline K-feldspar in addition to biotite and olivine. Pronounced alteration and sericitization observed may point to possible mineralization in the study area.

4.1 Implications for Economic Geology, and Water Resource Potentials of The Study Area

Economic geology deals with the study of/and analysis of geological materials to determine its profit potentials. It is therefore aimed at deliberating on the influence of geology on mineral mining, construction materials, together with study of possible occurrence of metallic and nonmetallic deposits.

The area of study has not been explored for economic deposits in details based on available literatures. Granitic rocks in the study area due to their durability, strength and large occurrence are used for construction purposes. These rocks are quarried at a location about 10km beyond the study area at a village called Kona biyu by the local people. Also, sharp sand at channels in the study area and the lateritic soil derived from weathering of granitic rocks are used for construction works. Alteration mineralization and sericitization observed both in the field and laboratory analysis may be pointers to possible mineralization in the study area. Ground water occurrence in the basement rocks is restricted to fractures and shear zones or zones of intense weathering (Tijani, 1994). Streams generally flow from northern to southern parts and the major river that flows southwest is structurally controlled.

5. Conclusion

The field and petrographic studies reveal that older granites constitute the predominant rock units in the area. The major structural elements, joints and faults and the predominant NE-SW and NW-SE trends show features which are indicative of later stage of the Pan-African orogeny (450-750 Ma.) associated with the Nigerian basement complex. Rocks in the area underwent extensive deformation as shown by numerous fractures, joints and faults, and are highly altered and weathered in some places. This phenomenon has great significance for mineral, water and other geological resource potentials in the area that might need further investigations.

5.1 Recommendation

Previous workers (e.g. Olade 1976) ascribed the inadequate geochemical investigations in the basement complex of Nigeria to the paucity of major mineral deposits possibly due to ineffective past mineral exploration or unfavourable geochemical heritage, but the current study and ongoing research of unpublished geochemical results indicate a probable mineralization associated with amphibolite in the extreme northern part of the study area, water and other geological resource potentials. Therefore, more researches are recommended using improved methodologies to understand the petrogenesis, general geology and to explore for natural resources in the region.

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